LM2907 Tachometer/Speed Switch Building Block Applications

National Semiconductor
Application Note 162
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INTRODUCTION

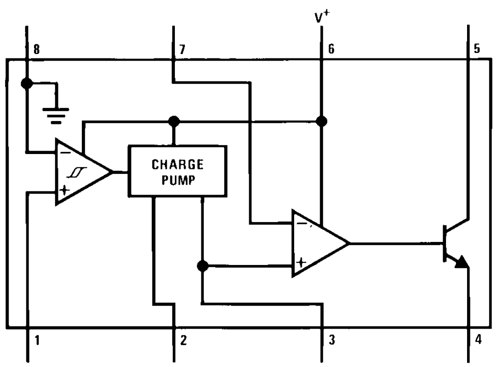
Frequency to voltage converters are available in a number of forms from a number of sources, but invariably require significant additional components before they can be put to use in a given situation. The LM2907, LM2917 series of devices was developed to overcome these objections. Both input and output interface circuitry is included on chip so that a minimum number of additional components is required to complete the function. In keeping with the systems building block concept, these devices provide an output voltage which is proportional to input frequency and provide zero output at zero frequency. In addition, the input may be referred to ground. The devices are designed to operate from a single supply voltage, which makes them particularly suitable for battery operation.

PART 1—GENERAL OPERATION PRINCIPLES

Circuit Description

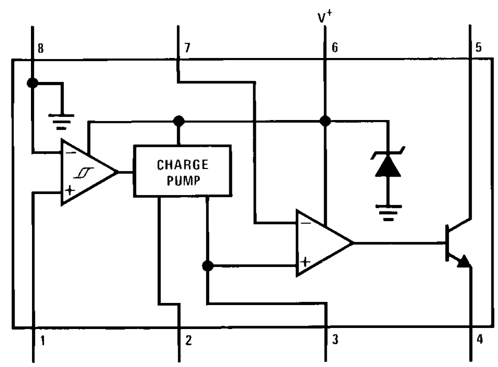
Referring to *Figure 1,* the family of devices all include three basic components: an input amplifier with built-in hysteresis; a charge pump frequency to voltage converter; and a versatile op amp/comparator with an uncommitted output transistor. LM2917 incorporates an active zener regulator on-chip. LM2907 deletes this option. Both versions are obtainable in 14-pin and in 8-pin dual-in-line molded packages, and to special order in other packages.

LM2907N-8



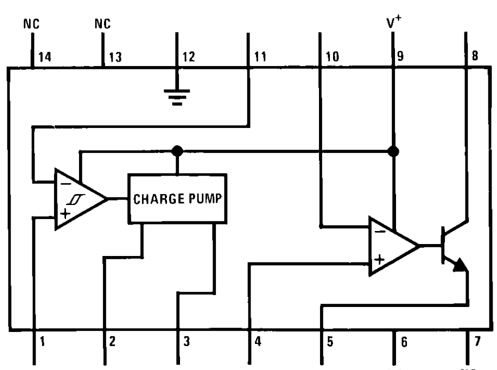
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LM2917N-8



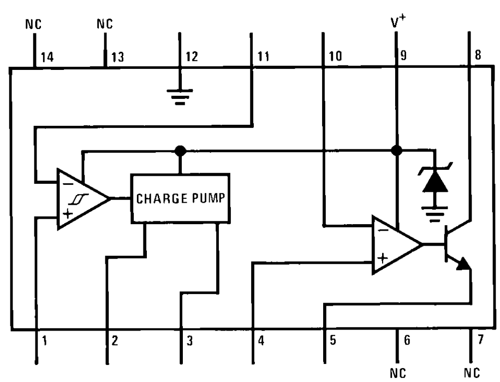
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LM2907N



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LM2917N



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FIGURE 1. Block Diagrams

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Input Hysteresis Amplifier

The equivalent schematic diagram is shown in *Figure 2.* Q1 through Q11 comprise the input hysteresis amplifier. Q1 through Q4 comprise an input differential amplifier which, by virtue of PNP level shifting, enables the circuit to operate with signals referenced to ground. Q7, Q8, D4, and D5 comprise an active load with positive feedback. This load behaves as a bi-stable flip-flop which may be set or reset depending upon the currents supplied from Q2 and Q3. Consider the situation where Q2 and Q3 are conducting equally, i.e. the input differential voltage is zero. Assuming Q7 to be conducting, it will be noted that the current from Q3 will be drawn by Q7 and Q8 will be in the ''OFF'' state. This allows the current from Q2 to drive Q7 in parallel with D4 and a small resistor. D4 and Q7 are identical geometry devices, so that the resistor causes Q7 to be biased at a higher level than D4. Thus Q7 will be able to conduct more current than Q3 provides. In order to reverse the state of Q7 and Q8, it will be necessary to reduce the current from Q2 below that provided by Q3 by an amount which is established by R1. It can be shown that this requires a differential input to Q1 and Q4, of approximately 15mV. Since the circuit is symmetrical, the threshold voltage to reverse the state is 15 mV in the other direction. Thus the input amplifier has built-in hysteresis at ±15 mV. This provides clean switching where noise may be present on the input signal, and allows total rejection of noise below this amplitude where there is no input signal.

Charge Pump

The charge pump is composed of Q12 through Q32. R4, R5, and R6 provide reference voltages equal to 1/4 and 3/4 of supply voltage to Q12 and Q13. When Q10 turns ''ON'' or ''OFF,'' the base voltage at Q16 changes by an amount equal to the voltage across R5, that is 1/2 V_{CC}. A capacitor connected between Pin 2 and ground is either charged by Q21 or discharged by Q22 until its voltage matches that on the base of Q16. When the voltage on Q16 base goes low, Q16 turns ''ON,'' which results in Q18 and Q26 turning on, which causes the current, sourced by Q19 and Q20, to be shunted to ground. Thus Q21 is unable to charge pin 2. Meanwhile, Q27 and Q30 are turned off permitting the 200 μA sourced by Q28 and Q29 to enter the emitters of Q31 and Q32 respectively. The current from Q31 is mirrored by Q22 through Q24 resulting in a 200 μA discharge current through pin 2. The external capacitor on pin 2 is thus discharged at a constant rate until it reaches the new base voltage on Q16. The time taken for this discharge to occur is given by:

$$t = \frac{CV}{I} \qquad (1)$$

where C = capacitor on pin 2
V = change in voltage on Q16 base
I = current in Q22

During this time, Q32 sources an identical current into pin 3. A capacitor connected to pin 3 will thus be charged by the same current for the same amount of time as pin 2. When the base voltage on Q16 goes high, Q18 and Q26 are turned off while Q27 and Q30 are turned ''ON.'' In these conditions, Q21 and Q25 provide the currents to charge the capacitors on pins 2 and 3 respectively. Thus the charge required to return the capacitor on pin 2 to the high level voltage is duplicated and used to charge the capacitor connected to pin 3. Thus in one cycle of input the capacitor on pin 3 gets charged twice with a charge of CV.

Thus the total charge pumped into the capacitor on pin 3 per cycle is:

$$Q = 2\,CV \qquad (2)$$

Now, since $V = V_{CC}/2$

then
$$Q = CV_{CC} \qquad (3)$$

A resistor connected between pin 3 and ground causes a discharge of the capacitor on pin 3, where the total charge drained per cycle of input signal is equal to:

$$Q1 = \frac{V3 \bullet T}{R}$$

where V3 = the average voltage on pin 3
T = period of input signal
R = resistor connected to pin 3

In equilibrium Q = Q1

$$\text{i.e., } CV_{CC} = \frac{V3 \bullet T}{R} \qquad (4)$$

and
$$V3 = V_{CC} \bullet \frac{RC}{T} \qquad (5)$$

or
$$V3 = V_{CC} \bullet R \bullet C \bullet f \qquad (6)$$

where f = input frequency

Op Amp/Comparator

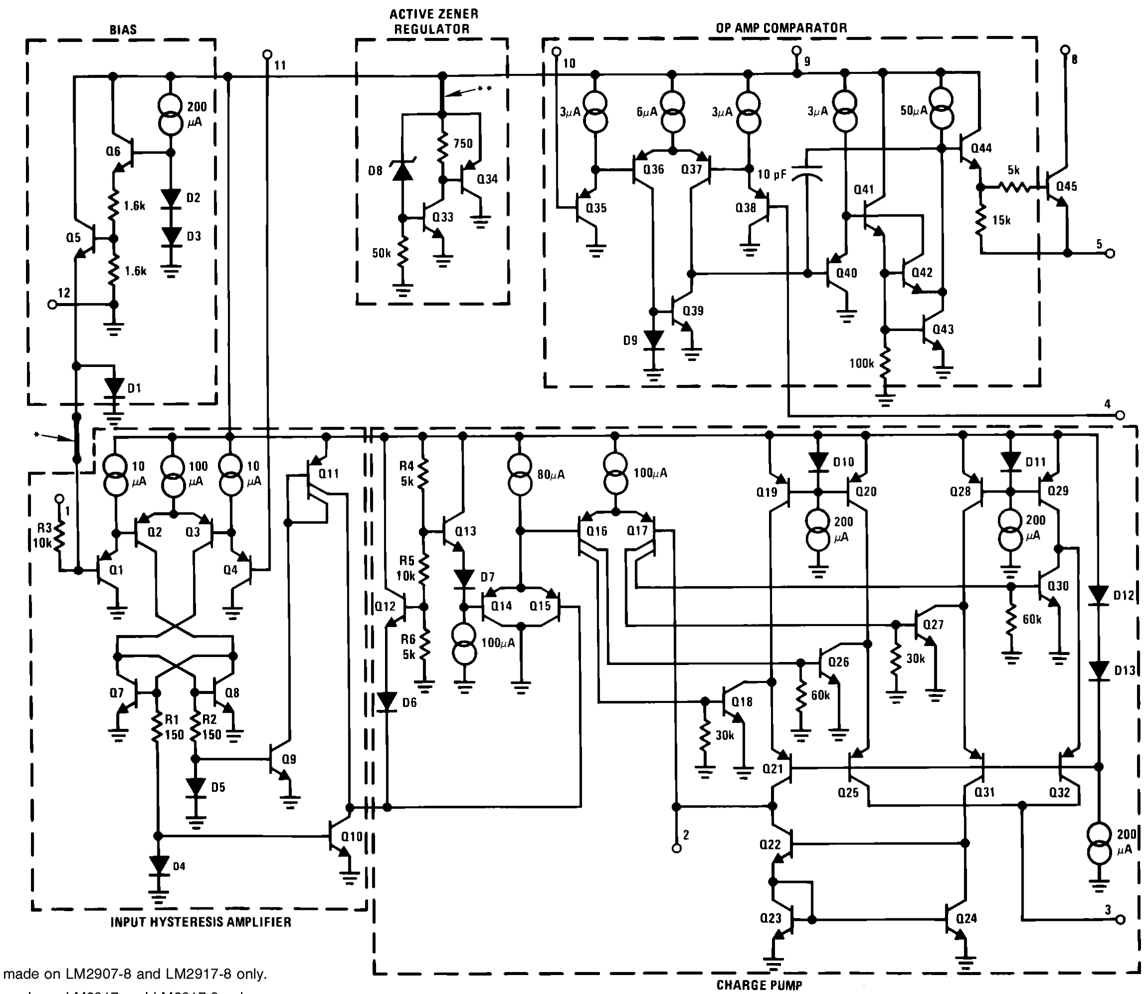
Again referring to *Figure 2,* the op amp/comparator includes Q35 through Q45. A PNP input stage again provides input common-mode voltages down to zero, and if pin 8 is connected to V_{CC} and the output taken from pin 5, the circuit behaves as a conventional, unity-gain-compensated operational amplifier. However, by allowing alternate connections of Q45 the circuit may be used as a comparator in which loads to either V_{CC} or ground may be switched. Q45 is capable of sinking 50 mA. Input bias current is typically 50 nA, and voltage gain is typically 200 V/mV. Unity gain slew rate is 0.2 V/μs. When operated as a comparator Q45 emitter will switch at the slew rate, or the collector of Q45 will switch at that rate multiplied by the voltage gain of Q45, which is user selectable.

Active Zener Regulator

The optional active zener regulator is also shown in *Figure 2.* D8 provides the voltage reference in conjunction with Q33. As the supply voltage rises, D8 conducts and the base voltage on Q33 starts to rise. When Q33 has sufficient base voltage to be turned ''ON,'' it in turn causes Q34 to conduct current from the power source. This reduces the current available for D8 and the negative feedback loop is thereby completed. The reference voltage is therefore the zener voltage on D8 plus the emitter base voltage of Q33. This results in a low temperature coefficient voltage.

Input Levels and Protection

In 8-pin versions of the LM2907, LM2917, the non-inverting input of the op amp/comparator is connected to the output of the charge pump. Also, one input to the input hysteresis amplifier is connected to ground. The other input (pin 1) is then protected from transients by, first a 10kΩ series resis-



*Note: This connection made on LM2907-8 and LM2917-8 only.

**Note: This connection made on LM2917 and LM2917-8 only.

Note: Pin numbers refer to 14-pin package.

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FIGURE 2. Equivalent Schematic Diagram

tor, R3 *(Figure 2)* which is located in a floating isolation pocket, and secondly by clamp diode D1. Since the voltage swing on the base of Q1 is thus restricted, the only restriction on the allowable voltage on pin 1 is the breakdown voltage of the 10 kΩ resistor. This allows input swings to ±28V. In 14-pin versions the link to D1 is opened in order to allow the base of Q1 to be biased at some higher voltage.

Q5 clamps the negative swing on the base of Q1 to about 300 mV. This prevents substrate injection in the region of Q1 which might otherwise cause false switching or erroneous discharge of one of the timing capacitors.

The differential input options (LM2907-14, LM2917-14), give the user the option of setting his own input switching level and still having the hysteresis around that level for excellent noise rejection in any application.

HOW TO USE IT

Basic f to V Converter

The operation of the LM2907, LM2917 series is best understood by observing the basic converter shown in *Figure 3.* In this configuration, a frequency signal is applied to the input of the charge pump at pin 1. The voltage appearing at pin 2 will swing between two values which are approximately 1/4 $(V_{CC}) - V_{BE}$ and 3/4 $(V_{CC}) - V_{BE}$. The voltage at pin 3 will have a value equal to $V_{CC} \bullet f_{IN} \bullet C1 \bullet R1 \bullet K$, where K is the gain constant (normally 1.0).

The emitter output (pin 4) is connected to the inverting input of the op amp so that pin 4 will follow pin 3 and provide a low impedance output voltage proportional to input frequency. The linearity of this voltage is typically better than 0.3% of full scale.

Choosing R1, C1 and C2

There are some limitations on the choice of R1, C1 and C2 *(Figure 3)* which should be considered for optimum performance. C1 also provides internal compensation for the charge pump and should be kept larger than 100 pF. Smaller values can cause an error current on R1, especially at low temperatures. Three considerations must be met when choosing R1.

First, the output current at pin 3 is internally fixed and therefore V3 max, divided by R1, must be less than or equal to this value.

$$\therefore R1 \geq \frac{V3\ max}{I_{3MIN}}$$

where V3 max is the full scale output voltage required

1_{3MIN} is determined from the data sheet (150 μA)

Second, if R1 is too large, it can become a significant fraction of the output impedance at pin 3 which degrades linearity. Finally, ripple voltage must be considered, and the size of C2 is affected by R1. An expression that describes the ripple content on pin 3 for a single R1, C2 combination is:

$$V_{RIPPLE} = \frac{V_{CC}}{2} \bullet \frac{C1}{C2}\left(1 - \frac{V_{CC} \bullet f_{IN} \bullet C1}{I_2}\right) \text{p-p}$$

It appears R1 can be chosen independent of ripple, however response time, or the time it takes V_{OUT} to stabilize at a new frequency increases as the size of C2 increases, so a compromise between ripple, response time, and linearity must be cosen carefully. R1 should be selected according to the following relationship:

C is selected according to:

$$C1 = \frac{V3\ \text{Full Scale}}{R1 \bullet V_{CC} \bullet f_{FULL\ SCALE}}$$

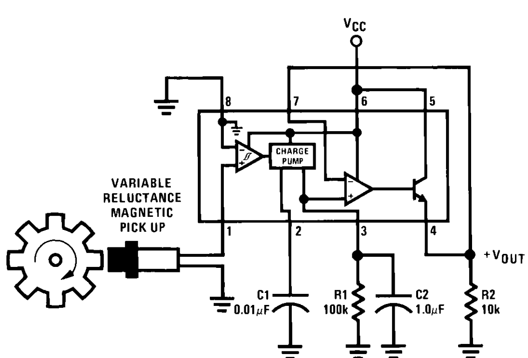
Next decide on the maximum ripple which can be accepted and plug into the following equation to determine C2:

$$C2 = \frac{V_{CC}}{2} \bullet \frac{C1}{V_{RIPPLE}}\left(1 - \frac{V_3}{R_1 I_2}\right)$$

The kind of capacitor used for timing capacitor C1 will determine the accuracy of the unit over the temperature range. *Figure 15* illustrates the tachometer output as a function of temperature for the two devices. Note that the LM2907 operating from a fixed external supply has a negative temperature coefficient which enables the device to be used with capacitors which have a positive temperature coefficient and thus obtain overall stabililty. In the case of the LM2917 the internal zener supply voltage has a positive coefficient which causes the overall tachometer output to have a very low temperature coefficient and requires that the capacitor temperature coefficient be balanced by the temperature coefficient of R1.

Using Zener Regulated Options (LM2917)

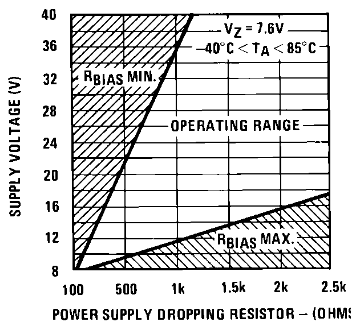
For those applications where an output voltage or current must be obtained independently of the supply voltage variations, the LM2917 is offered. The reference typically has an 11Ω source resistance. In choosing a dropping resistor from the unregulated supply to the device note that the tachometer and op amp circuitry alone require about 3 mA at the voltage level provided by the zener. At low supply voltages,



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FIGURE 3. Basic f to V Converter

there must be some current flowing in the resistor above the 3 mA circuit current to operate the regulator. As an example, if the raw supply varies from 9V to 16V, a resistance of 470Ω will minimize these zener voltage variations to 160 mV. If the resistor goes under 400Ω or over 600Ω the zener variation quickly rises above 200 mV for the same input variation. Take care also that the power dissipation of the IC is not exceeded at higher supply voltages. *Figure 4* shows suitable dropping resistor values.

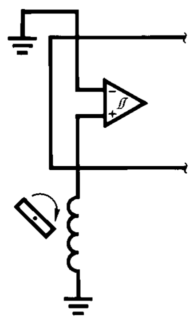


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FIGURE 4. Zener Regular Bias Resistor Range

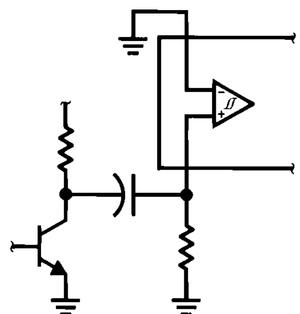
Input Interface Circuits

The ground referenced input capability of the LM2907-8 allows direct coupling to transformer inputs, or variable reluctance pickups. *Figure 5(a)* illustrates this connection. In many cases, the frequency signal must be obtained from another circuit whose output may not go below ground. This may be remedied by using ac coupling to the input of the LM2907 as illustrated in *Figure 5(b).* This approach is very suitable for use with phototransistors for optical pickups. Noisy signal sources may be coupled as shown in *Figure 5(c).* The signal is bandpass filtered. This can be used, for example, for tachometers operating from breakerpoints on a conventional Kettering ignition system. Remember that the minimum input signal required by the LM2907 is only 30 mVp-p, but this signal must be able to swing at least 15 mV on either side of the inverting input. The maximum signal which can be applied to the LM2907 input, is ±28V. The input bias current is a typically 100 nA. A path to ground must be provided for this current through the source or by other means as illustrated. With 14-pin package versions of LM2907, LM2917, it is possible to bias the inverting input to the tachometer as illustrated in *Figure 5(d).* This enables the circuit to operate with input signals that do not go to ground, but are referenced at higher voltages. Alternatively, this method increases the noise immunity where large signal



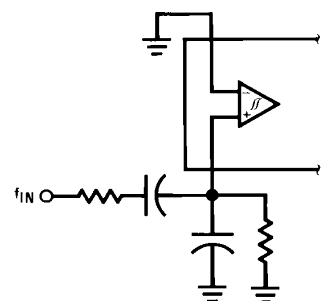
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(a) Ground Referenced Inputs



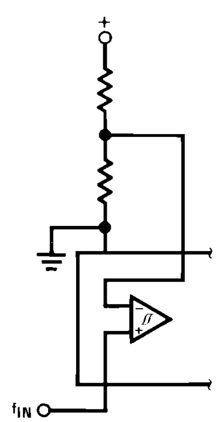
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(b) AC Coupled Input



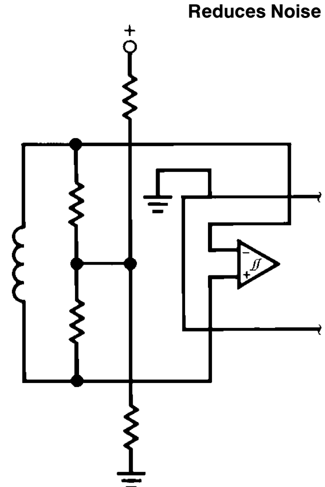
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(c) Bandpass Filtered Input Reduces Noise



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(d) Above Ground Sensing



TL/H/7451–12

(e) High Common-Mode Rejection Input Circuit

FIGURE 5. Tachometer Input Configurations

levels are available but large noise signals on ground are also present. To take full advantage of the common-mode rejection of the input differential stage, a balanced bias configuration must be provided. One such circuit is illustrated in *Figure 5(e).* With this arrangement, the effective common-mode rejection may be virtually infinite, owing to the input hysteresis.

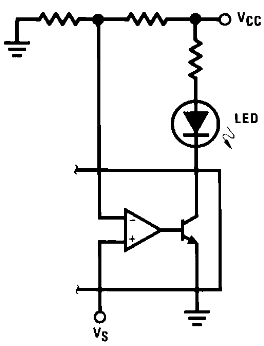
Output Configurations

LM2907, LM2917 series devices incorporate an unusually flexible op amp/comparator device on-chip for interfacing with a wide variety of loads. This flexibility results from the availability of both the collector and emitter of the output transistor which is capable of driving up to 50 mA of load current. When the non-inverting input is higher than the inverting input, this output transistor is turned "ON". It may be used to drive loads to either the positive or the negative supply with the emitter or collector respectively connected to the other supply. For example, *Figure 6(a),* a simple speed switch can be constructed in which the speed signal derived from the frequency to voltage converter is compared to a reference derived simply by a resistive divider from the power supply. When the speed signal exceeds the reference, the output transistor turns on the light emitting diode in the load. A small current limiting resistor should be placed in series with the output to protect the LED and the output transistor.

This circuit has no hysteresis in it, i.e., the turn "ON" and turn "OFF" speed voltages are essentially equal. In cases where speed may be fluctuating at a high rate and a flashing LED would be objectionable, it is possible to incorporate hysteresis so that the switch-on speed is above the switch-off speed by a controlled amount. Such a configuration is illustrated in *Figure 6(b). Figure 6(c)* shows how a grounded load can also be switched by the circuit. In this case, the current limiting resistor is placed in the collector of the power transistor. The base current of the output transistor (Q45) is limited by a 5 kΩ base resistor (see *Figure 2*). This raises the output resistance so that the output swing will be reduced at full load.

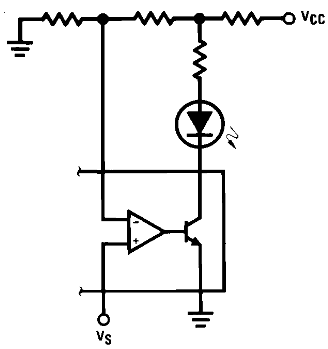
The op amp/comparator is internally compensated for unity gain feedback configurations as in *Figure 6(d).* By directly connecting the emitter output to the non-inverting input, the op amp may be operated as a voltage follower. Note that a load resistor is required externally. The op amp can also be operated, of course, as an amplifier, integrator, active filter, or in any other normal operational amplifier configuration.

One unique configuration which is not available with standard operational amplifiers, is shown in *Figure 6(e).* Here the collector of the output transistor is used to drive a load



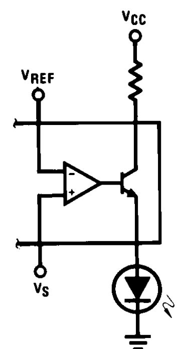
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(a) Switching an LED



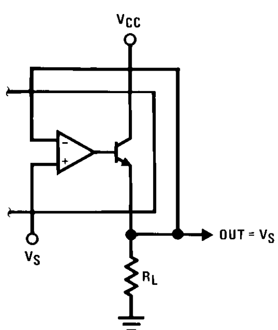
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(b) Adding Hysteresis to LED Switch



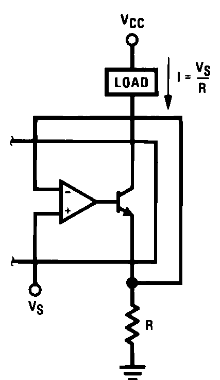
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(c) Switching a Grounded Load



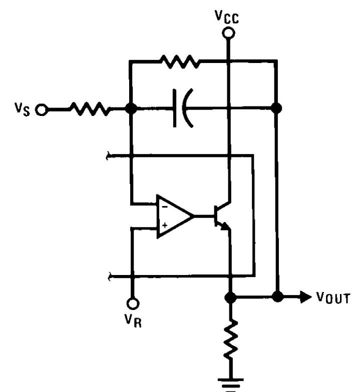
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(d) Voltage Follower



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(e) Voltage to Current Converter



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(f) Integrator

FIGURE 6. Output Configurations

with a current which is proportional to the input voltage. In other words, the circuit is operating as a voltage to current converter. This is ideal for driving remote signal sensors and moving coil galvanometers. *Figure 6(f)* shows how an active integrator can be used to provide an output which falls with increasing speed.

These are the basic configurations obtainable with the op amp/comparator. Further combinations can be seen in the applications shown in Part II of this application note.

Transient Protection

Many application areas use unregulated power supplies which tend to expose the electronics to potentially damaging transients on the power supply line. This is particularly true in the case of automotive applications where two such transients are common.[1] First is the load dump transient. This occurs when a dead battery is being charged at a high current and the battery cable comes loose, so that the current in the alternator inductance produces a positive transient on the line in the order of 60V to 120V. The second transient is called field decay. This occurs when the ignition is turned "OFF" and the energy stored in the field winding of the alternator causes a negative 75V transient on the ignition line.

Figure 7 illustrates methods for protecting against these and other transients. *Figure 7(a)* shows a typical situation in which the power supply to the LM2907 can be provided through a dropping resistor and regulated by an external zener diode Z1, but the output drive is required to operate from the full available supply voltage. In this case, a separate protection zener Z2 must be provided if the voltage on the power line is expected to exceed the maximum rated voltage of the LM2907.

In *Figure 7(b)* and *Figure 7(c),* the output transistor is required only to drive a simple resistive load and no secondary protection circuits are required. (Note that the dropping resistor to the zener also has to supply current to the output circuit). With the foregoing circuits, reverse supply protection is supplied by the forward biased zener diode. This device should be a low forward resistance unit in order to limit the maximum reverse voltage applied to the integrated circuit. Excessive reverse voltage on the IC can cause high currents to be conducted by the substrate diodes with consequent danger of permanent damage. Up to 1V negative can generally be tolerated. Versions with internal zeners may be self-protecting depending on the size of dropping resistor used. In applications where large negative voltage

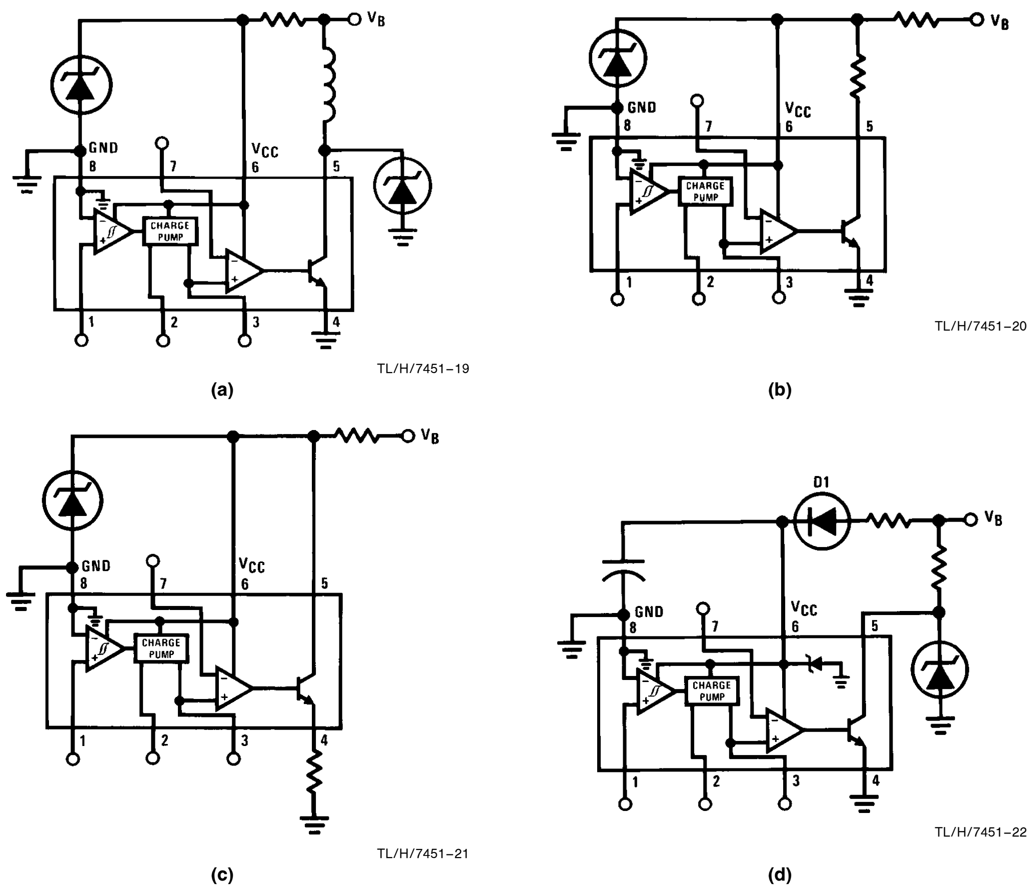


FIGURE 7. Transient Protection Schemes

transients may be anticipated, a blocking diode may be connected in the power supply line to the IC as illustrated in *Figure 7(d).* During these negative transients, the diode D1 will be reverse biased and prevent reverse currents flowing in the IC. If these transients are short and the capacitor C1 is large enough, then the power to the IC can be sustained. This is useful to prevent change of state or change of charge in in systems connected to it.

Temperature Ranges and Packaging Considerations

The LM2907, LM2917 series devices are specified for operation over the temperature range −40°C to +85°C.

The devices are normally packaged in molded epoxy, dual-in-line packages. Other temperature ranges and other packages are availabe to special order. For reliability requirements beyond those of normal commercial application where the cost of military qualification is not bearable, other programs are available such as B+.

PART II—APPLICATIONS

INTRODUCTION

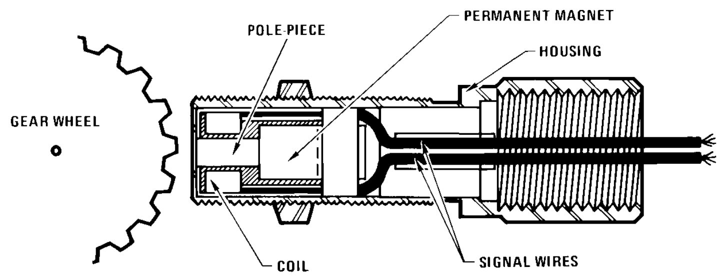
The LM 2907, LM2917 series devices were designed not only to perform the basic frequency to voltage function required in many systems, but also to provide the input and output interface so often needed, so that low cost implementations of complete functions are available.

The concept of building blocks requires that a function be performed in the same way as it can be mathematically defined. In other words, a frequency to voltage converter will provide an output voltage proportional to frequency which is independent of the input voltage or other input parameters, except the frequency. In the same way, the output voltage will be zero when the input frequency is zero. These features are built into the LM2907.

Applications for the device range from simple speed switch for anti-pollution control device functions in automobiles, to motor speed controls in industrial applications. The applications circuits which follow are designed to illustrate some of the capabilities of the LM2907. In most cases, alternative input or output configurations can be mixed and matched at will and other variations can be determined from the description in Part I of this application note. For complete specifications, refer to the data sheet.

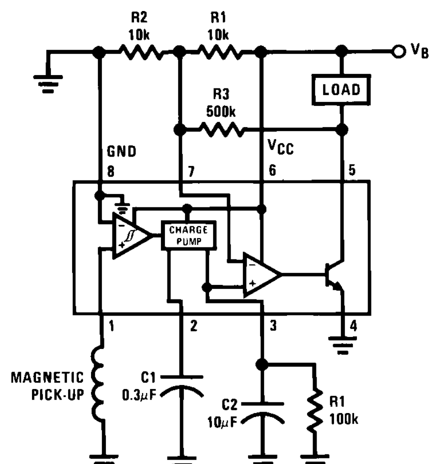
Speed Switches

Perhaps the most natural application of the LM2907 is in interfacing with magnetic pickups, such as the one illustrated in *Figure 8* to perform speed switching functions. As an example, New York taxies are required to change the intensity of the warning horn above and below 45 mph. Other examples include an over-speed warning, where a driver may set the desired maximum speed and have an audible



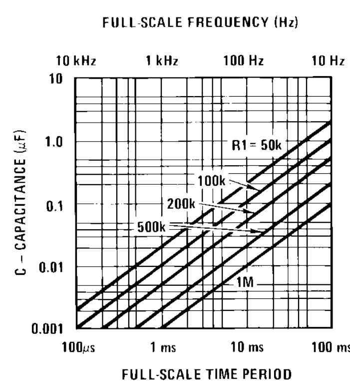
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FIGURE 8. Typical Magnetic Pickup



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FIGURE 9. Simple Speed Switch Load is Energized when $f_{IN} > \frac{1}{2C1R1}$



TL/H/7451–25

FIGURE 10. RC Selection Chart

or visual warning of speeds in excess of that level. Many anti-pollution devices included on several recent automobile models have included a speed switch to disable the vacuum advance function until a certain speed is attained[2]. A circuit which will perform these kind of functions is shown in *Figure 9.* A typical magnetic pickup for automotive applications will provide a thousand pulses per mile so that at 60 mph the incoming frequency will be 16.6 Hz. If the reference level on the comparator is set by two equal resistors R1 and R2 then the desired value of C1 and R1 can be determined from the simple relationship:

$$\frac{V_{CC}}{2} = V_{CC} \bullet C1 \bullet R1 \bullet f.$$

or $$C1R1f = 0.5$$

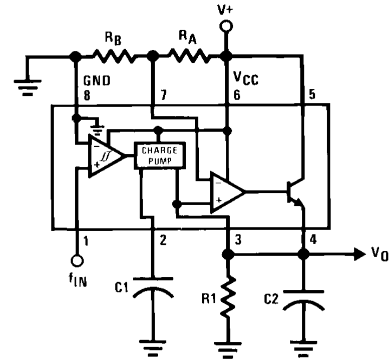
and hence $$C1R1 = 0.03$$

From the RC selection chart in *Figure 10* we can choose suitable values for R1 and C1. Examples are 100 kΩ and 0.3 μF. The circuit will then switch at approximately 60 mph with the stated input frequency relationship to speed. To determine the ripple voltage refer back to the equation for ripple voltage (under "Choosing R1, C1 and C2"). From this we can determine that there will be about 10 mV of ripple at the switching level. To prevent this from causing chattering of the load a certain amount of hysteresis is added by including R3. This will provide typically 1% of supply as a hysteresis or 1.2 mph in the example. Note that since the reference to the comparator is a function of supply voltage as is the output from the charge pump there is no need to regulate the power supply. The frequency at which switching occurs is independent of supply voltage.

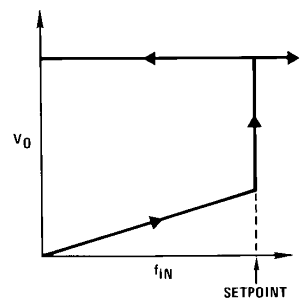
In some industrial applications it is useful to have an indication of past speed excesses, for example in notifying the need for checking of bearings. The LM2907 can be made to latch until the power supply is turned "OFF" in the case where the frequency exceeds a certain limit, by simply connecting the output transistor emitter back to the non-inverting input of the comparator as shown in *Figure 11.* It can also serve to shut off a tape recorder or editing machine at the end of a rewind cycle. When the speed suddenly increases, the device will sense the condition and shut down the motor.

Analog Displays

The LM2907, LM2917 series devices are particularly useful for analog display of frequency inputs. In situations where the display device is a moving coil instrument the advantages of the uncommitted output transistor can be realized by providing a current drive to the meter. This avoids temperature tracking problems with the varying meter resistance and enables high resistance instruments to be driven accurately with relatively large voltages as illustrated in *Figure 12.* The LM2917 version is employed here to provide a regulated current to the instrument. The onboard 7.6V zener is compatible with car and boat batteries and enables the moving coil instrument to employ the full battery voltage for its deflection. This enables high torque meters to be used. This is particularly useful in high vibration environments such as boats and motorcycles. In the case of boats, the most common speed pickup for the knot meter employs a rotating propeller driving a magnetic pickup device. Meteorologists employ a large number of anemometers for measuring wind velocities and these are frequently coupled by a magnetic pickup. In examples like these, where there is frequently a large distance between the display device and the sensor, the configuration of *Figure 13* can be usefully employed to cut down on the number of wires needed. Here the output current is conducted along the supply line so that a local current sensing device in the supply line can be used to get a direct reading of the frequency at the remote location where the electronics may also be situated. The small zero speed offset due to the device quiescent current may be compensated by offsetting the zero on the display device. This also permits one display device to be shared between several inputs.



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TL/H/7451–27

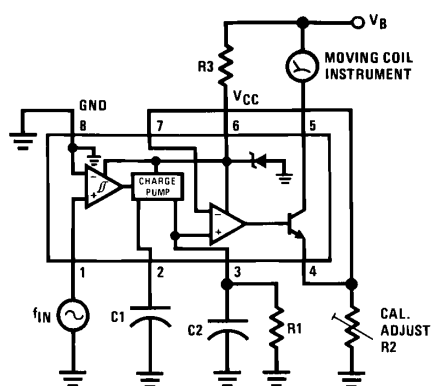
$V_O = F_{IN}V + R1\,C1$

$\text{SETPOINT} = V + \frac{RB}{RD + RA}$

Latchup occurs when $F_{IN} = \frac{RB}{RA + RB}\frac{1}{R1\,C1}$

Independent of V + !

FIGURE 11. Overspeed Latch



TL/H/7451–28

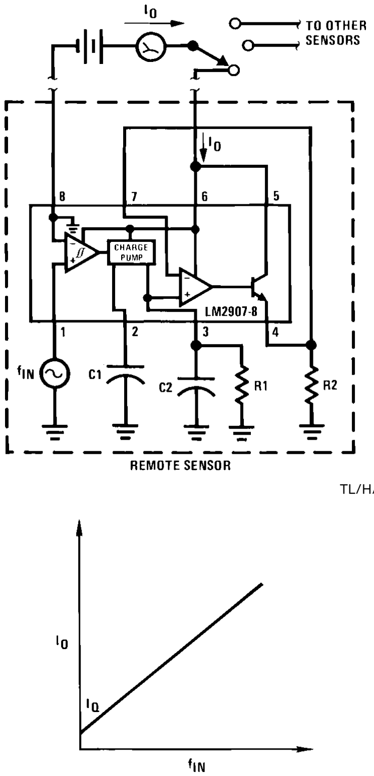
FIGURE 12. Analog Display of Frequency

Automotive Tachometer

Not all inputs are derived from variable reluctance magnetic pickups; for example, in spark ignition engines the tachometer is generally driven from the spark coil. An interface circuit for this situation is shown in *Figure 14.* This tachometer can be set up for any number of cylinders by linking the appropriate timing resistor as illustrated. A 500Ω trim resistor can be used to set up final calibration. A protection circuit composed of a 10Ω resistor and a zener diode is also shown as a safety precaution against the transients which are to be found in automobiles.

Motor Speed Controls

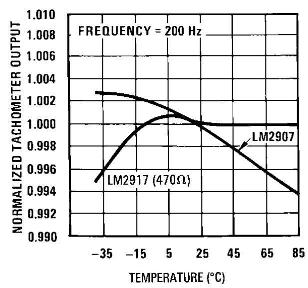
DC motors with or without brushes can be purchased with ac tachometer outputs already provided by the manufacturer[3]. With these motors in combination with the



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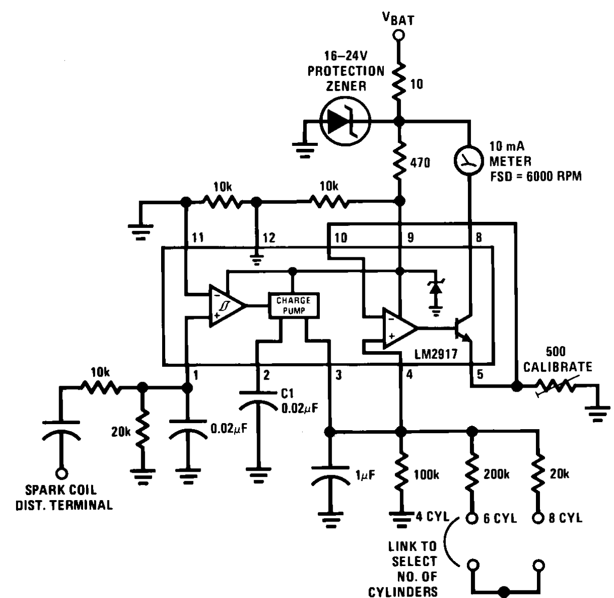
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FIGURE 13. Two Wire Remote Speed Sensor



TL/H/7451–32

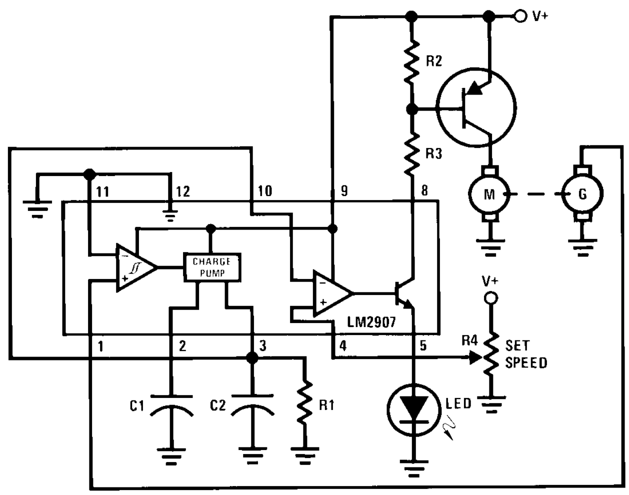
FIGURE 15. Normalized Tachometer Output vs. Temperature



TL/H/7451–31

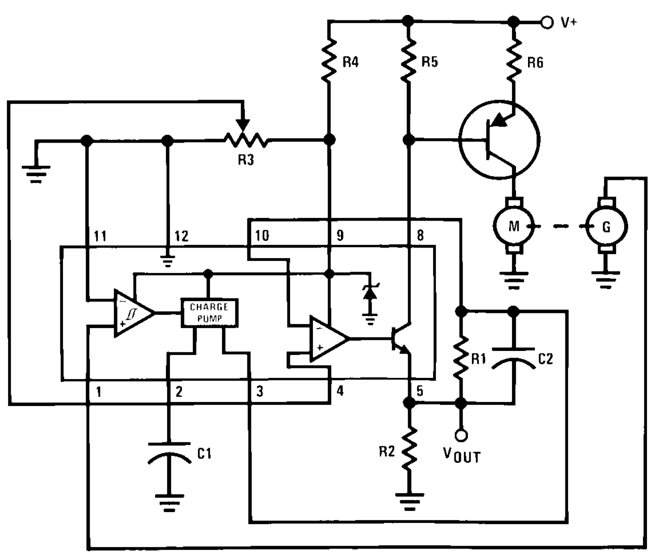
FIGURE 14. Gasoline Engine Tachometer

LM2907, a very low cost speed control can be constructed. In *Figure 16* the most simple version is illustrated where the tachometer drives the non-inverting input of the comparator up towards the preset reference level. When that level is reached, the output is turned off and the power is removed from the motor. As the motor slows down, the voltage from the charge pump output falls and power is restored. Thus speed is maintained by operating the motor in a switching mode. Hysteresis can be provided to control the rate of switching. An alternative approach which gives proportional control is shown in *Figure 17.* Here the charge pump integrator is shown in a feedback connection around the operational amplifier. The output voltage for zero speed is equal to the reference voltage set up on the potentiometer on the non-inverting input. As speed increases, the charge pump puts charge into capacitor C2 and causes the output V_{OUT} to fall in proportion to speed. The output current of the op amp transistor is used to provide an analog drive to the motor. Thus as the motor speed approaches the reference level, the current is proportionately reduced to the motor so that the motor gradually comes up to speed and is maintained without operating the motor in a switching mode. This is particularly useful in situations where the electrical noise generated by the switching mode operation is objectionable. This circuit has one primary disadvantage in that it has poor load regulation. A third configuration is shown in *Figure 18.* This employs an LM2907-8 acting as a shunt mode regulator. It also features an LED to indicate when the device is in regulation.



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FIGURE 16. Motor Speed Control



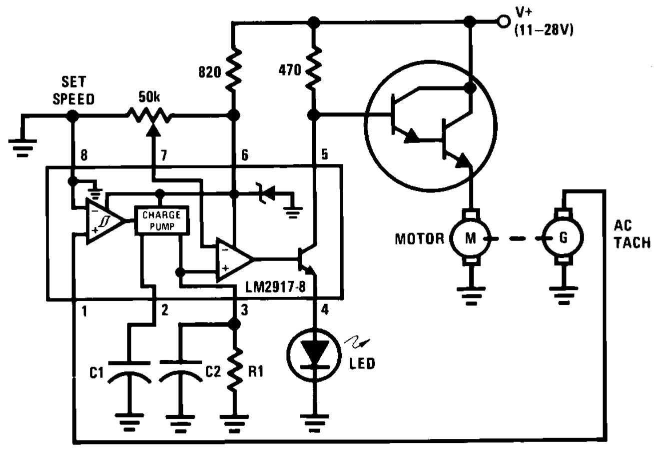
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FIGURE 17. Motor Speed Control with Proportional Drive

Position Sensing

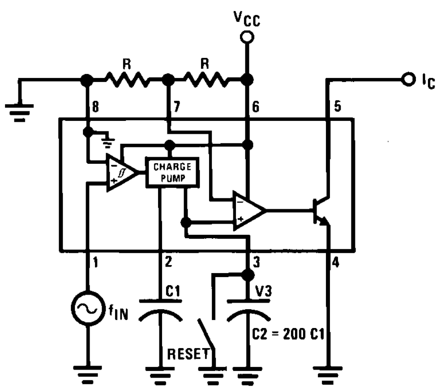
In addition to their use to complete tachometer feedback loops, used in position transducer circuits, the LM2907, LM2917 devices can also be used as position transducers. For example, the timing resistor can be removed from pin 3 so that the output current produces a staircase instead of a fixed dc level. If the magnetic pickup senses passing notches or items, a staircase signal is generated which can then be compared with a reference to initiate a switching action when a specified count is reached. For example, *Figure 19* shows a circuit which will count up a hundred input pulses and then switch on the output stage. Examples of this application can be found in automated packaging operations or in line printers.

The output of the tachometer is proportional to the product of supply voltage, input frequency, a capacitor and a resistor. Any one of these may be used as the input variable or they may be used in combination to produce multiplication. An example of a capacitive transducer is illustrated in *Figure 20,* where a fixed input frequency is employed either from the 60 Hz line as a convenient source or from a stable oscillator. The capacitor is a variable element mechanically coupled to the system whose position is to be sensed. The output is proportional to the capacitance value, which can be arranged to have any desired relationship to the mechanical input by suitable shaping of the capacitor electrodes.

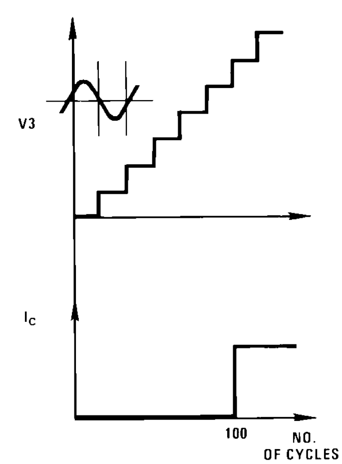


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FIGURE 18. Motor Speed Control

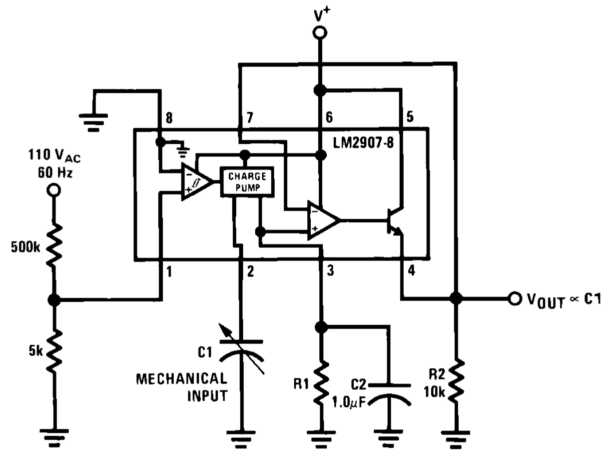


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FIGURE 19. Staircase Counter



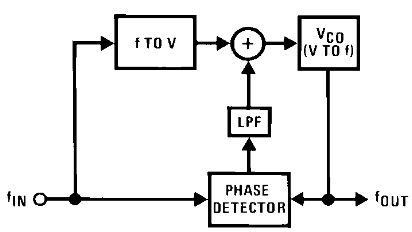
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FIGURE 20. Capacitive Transducer

Analog Systems Building Block

The LM2907, LM2917 series characterize systems building block applications by the feature that the output from the device is proportional only to externally programmed inputs. Any or all of these inputs may be controlled inputs to provide the desired output. For example, in *Figure 20* the capacitance transducer can be operated as a multiplier. In flow measurement indicators, the input frequency can be a variable depending on the flow rate, such as a signal generated from a paddle wheel, propeller or vortex sensor[4]. The capacitor can be an indication of orifice size or aperture size, such as in a throttle body. The product of these two will indicate volume flow. A thermistor could be added to R1 to convert the volume flow to mass flow. So a combination of these inputs, including control voltage on the supply, can be used to provide complex multiplicative analog functions with independent control of the variables.

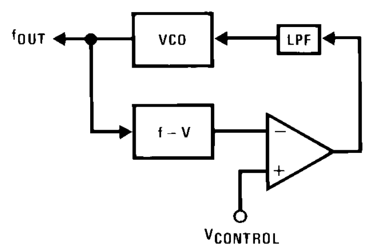
Phase-locked loops (PLL) are popular today now that low cost monolithic implementations are available off the shelf. One of their limitations is the narrow capture range and hold-in range. The LM2907 can be employed as a PLL helper. The configuration is shown in *Figure 21.* The LM2907 here serves the function of a frequency-to-voltage converter which puts the VCO initially at approximately the right frequency to match the input frequency. The phase detector is then used to close the gap between VCO and input frequency by exerting a control on the summing point. In this way, given proper tracking between the frequency-to-voltage converter and the VCO, (which is a voltage-to-frequency converter), a wide-range phase loop can be developed.



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FIGURE 21. Phase-Locked Loop Helper
Added f to V Greatly Increases Capture and Hold Range

The linearity of voltage controlled oscillators can be improved by employing the LM2907 as a feedback control element converting the frequency back to voltage and comparing with the input voltage. This can often be a lower cost solution to linearizing the VCO than by working directly on the VCO itself in the open loop mode. The arrangement is illustrated in *Figure 22.*



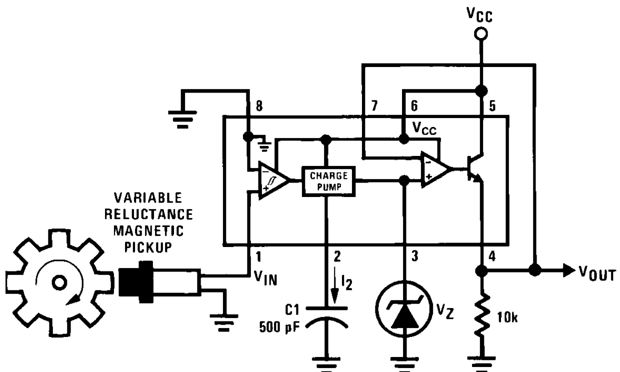
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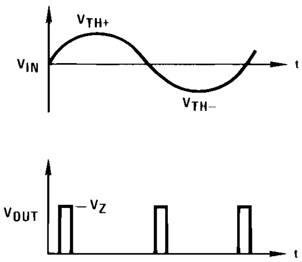
FIGURE 22. Feedback Controlled VCO

Digital Interface

A growing proportion of the complex control systems today are being controlled by microprocessors and other digital devices. Frequently they require inputs to indicate position or time from some mechanical input. The LM2907 can be used to provide zero crossing datum to a digital system using the circuits illustrated in *Figure 23.* At each zero crossing of the input signal the charge pump changes the state of capacitor C1 and provides a one-shot pulse into the zener diode at pin 3. The width of this pulse is controlled by the internal current of pin 2 and the size of capacitor C1 as well as by the supply voltage. Since a pulse is generated by each zero crossing of the input signal we call this a ''two-shot'' instead of a ''one-shot'' device and this can be used for doubling the frequency that is presented to the microprocessor control system. If frequency doubling is not required and a square wave output is preferred, the circuit of *Figure 24* can be employed. In this case, the output swing is the same as the swing on pin 2 which is a swing of half supply voltage starting at 1 V_{BE} below one quarter of supply and going to 1 V_{BE} below three-quarters of supply. This can be increased up to the full output swing capability by reducing or removing the negative feedback around the op amp.

The staircase generator shown in *Figure 19* can be used as an A-D converter. A suitable configuration is shown in *Figure 25.* To start a convert cycle the processor generates a reset pulse to discharge the integrating capacitor C2. Each complete clock cycle generates a charge and discharge cycle on C1. This results in two steps per cycle being added to C2. As the voltage on C2 increases, clock pulses are returned to the processor. When the voltage on C2 steps above the analog input voltage the data line is clamped and C2 ceases to charge. The processor, by counting the number of clock pulses received after the reset pulse, is thus loaded with a digital measure of the input voltage. By making C2/C1 = 1024 an 8-bit A-D is obtained.





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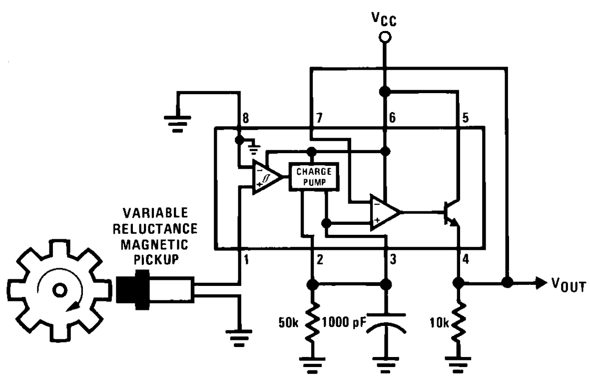
Pulse width $= \frac{V_{CC}}{2} \times \frac{C1}{I_2}$

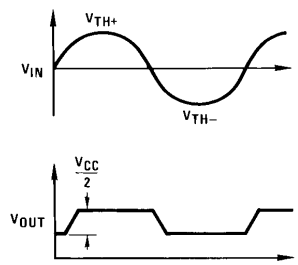
Input can be ±20 mV to ±28V

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Output frequency equal twice input frequency. Pulse width $= \frac{V_{CC}}{2} \times \frac{C1}{I_2}$ Pulse height $= V_{ZENER}$

FIGURE 23. "Two-Shot" Zero Crossing Detector

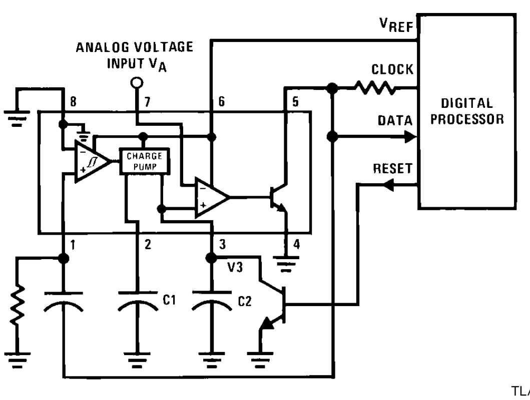


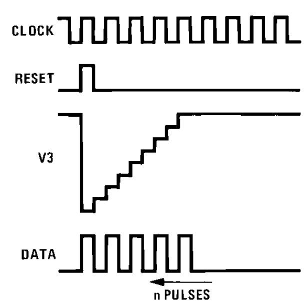


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FIGURE 24. Zero Crossing Detector and Line Drivers





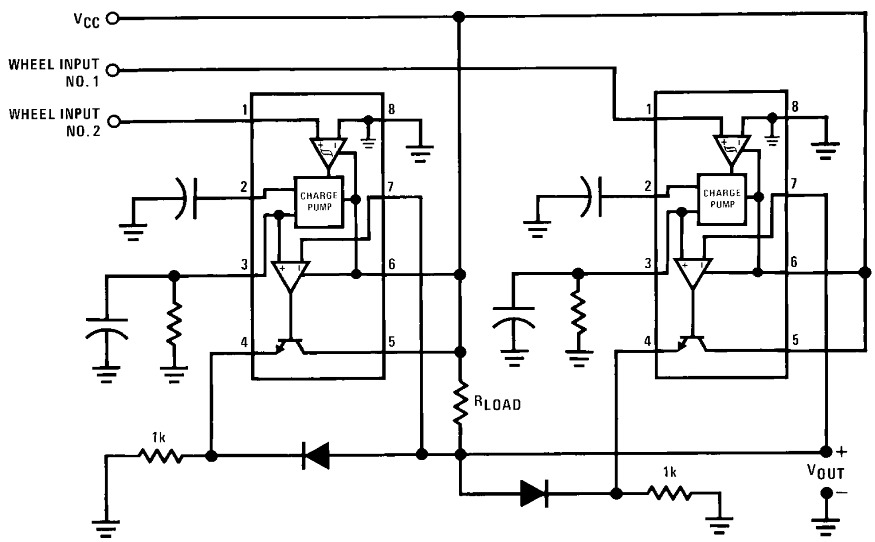
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TL/H/7451–45

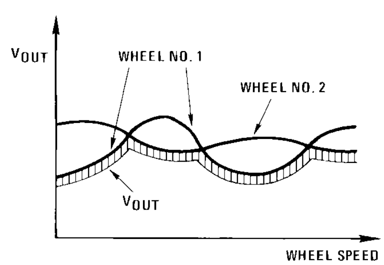
FIGURE 25. A-D Converter

Anti-Skid Circuit Functions

Motor Vehicle Standards 121 place certain stopping requirements on heavy vehicles which require the use of electronic anti-skid control devices.[5] These devices generally use variable reluctance magnetic pickup sensors on the wheels to provide inputs to a control module. One of the questions which the systems designer must answer is whether to use the average from each of the two wheels on a given axle or to use the lower of the two speeds or to use the higher of the two speeds. Each of the three functions can be generated by a single pair of LM2907-8 as illustrated in *Figures 26–28.* In *Figure 26* the input frequency from each wheel sensor is converted to a voltage in the normal manner. The op amp/comparator is connected with negative feedback with a diode in the loop so that the amplifier can only pull down on the load and not pull up. In this way, the outputs from the two devices can be joined together and the output will be the lower of the two input speeds. In *Figure 27* the output emitter of the onboard op amp provides the pullup required to provide a select-high situation where the output is equal to the higher of two speeds. The select average circuit in *Figure 28* saves components by allowing the two charge pumps to operate into a single RC network. One of the amplifiers is needed then to buffer the output and provide a low impedance output which is the average of the two input frequencies. The second amplifier is available for other applications.



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V_{OUT} is proportional to the lower of the two input wheel speeds

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FIGURE 26. "Select-Low" Circuit

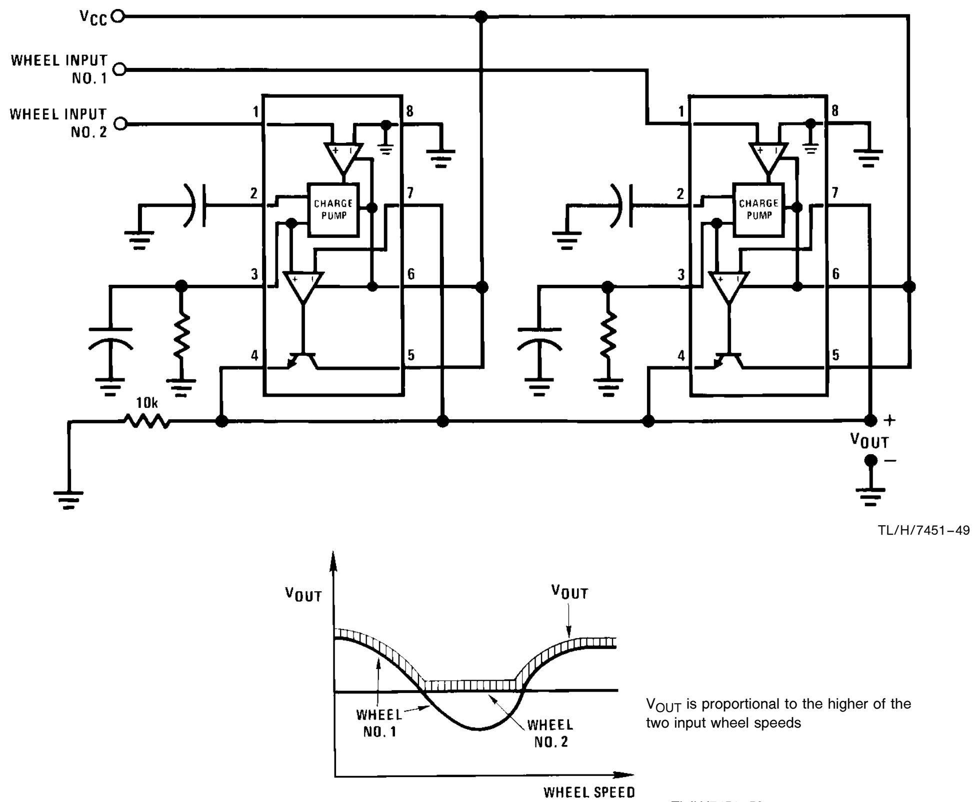


FIGURE 27. "Select-High" Circuit

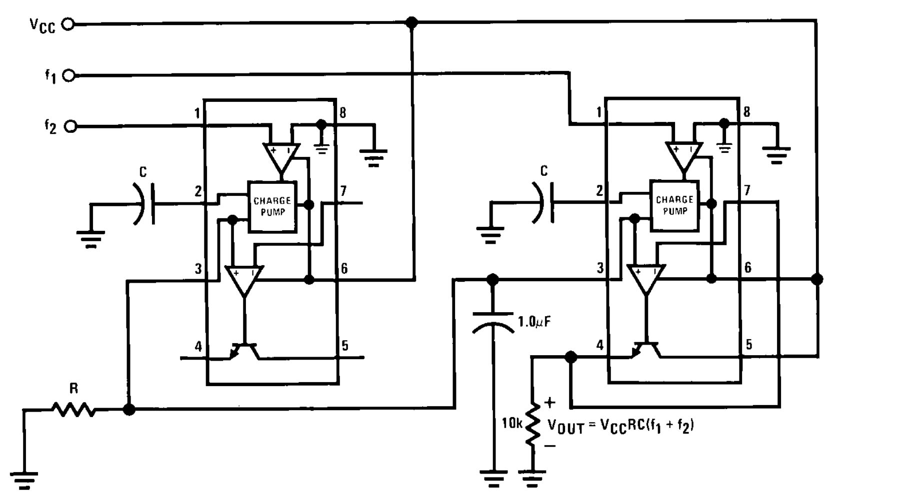


FIGURE 28. "Select-Average" Circuit

Transmission and Clutch Control Functions

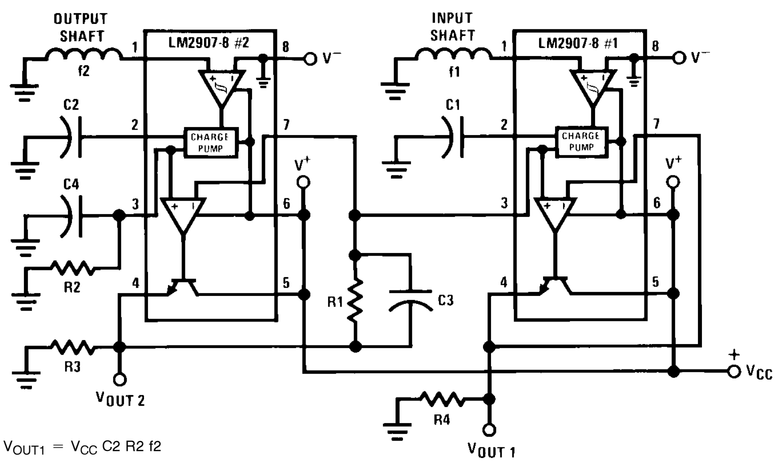
Electric clutches can be added to automotive transmissions to eliminate the 6% slip which typically occurs during cruise and which results in a 6% loss in fuel economy. These devices could be operated by a pair of LM2907's as illustrated in *Figure 29.* Magnetic pickups are connected to input and output shafts of the transmission respectively and provide frequency inputs f_1 and f_2 to the circuit. Frequency, f_2, being the output shaft speed, is also a measure of vehicle road speed. Thus the LM2907-8 No. 2 provides a voltage proportional to road speed at pin 3. This is buffered by the op amp in LM2907-8 No. 1 to provide a speed output V_{OUT1} on pin 4. The input shaft provides charge pulses at the rate of $2f_1$ into the inverting node of op amp 2. This node has the integrating network R1, C3 going back to the output of the op amp so that the charge pulses are integrated and provide an inverted output voltage proportional to the input speed. Thus the output V_{OUT2} is proportional to the difference between the two input frequencies. With these two signals—the road speed and the difference between road speed and input shaft speed—it is possible to develop a number of control functions including the electronic clutch and a complete electronic transmission control. (In the configuration shown, it is not possible for V_{OUT2} to go below zero so that there is a limitation to the output swing in this direction. This may be overcome by returning R3 to a negative bias supply instead of to ground.)

CONCLUSION

The applications presented in this note indicate that the LM2907, LM2917 series devices offer a wide variety of uses ranging from very simple low cost frequency to voltage conversion to complex systems building blocks. It is hoped that the ideas contained here have given suggestions which may help provide new solutions to old problems. Additional applications ideas are included in the data sheet, which should be referred to for all specifications and characteristics.

REFERENCES

1. Society of Automotive Engineers: Preliminary Recommended Environmental Practices for Electronic Equipment Design. October 1974.
2. See for example: Pollution Control Installers Handbook—California Bureau of Automotive Repair No. BAR H-001 § 5.5.4 NOX control systems.
3. TRW Globe Motors, 2275 Stanley Avenue, Dayton, Ohio 45404.
4. S.A.E. Paper #760018 Air Flow Measurement for Engine Control—Robert D. Joy.
5. Code of Federal Regulations. Title 49 Transportation; Chapter V—National Highway Traffic Safety Administration, Dept. of Transportation; Part 571—Federal Motor Vehicle Safety Standards; Standard No. 121.



$V_{OUT1} = V_{CC}\ C2\ R2\ f2$

$V_{OUT2} = V_{CC}\ (C2\ R2\ f2 - C1\ R1\ f1)$

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FIGURE 29. Transmission or Clutch Control Functions

National Semiconductor Corporation
1111 West Bardin Road
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Tel: 1(800) 272-9959
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